ANALYSIS OF AERIAL TANKER RE-ENGINING PROGRAMS

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PREFACE

The Air Force maintains a large but aging fleet of tanker aircraft used to extend the flying ranges of bombers for strategic nuclear missions and to assist other military aircraft in conventional non-nuclear contingencies. Several programs, most notably re-engining, are now in progress to refurbish and expand the performance of these aircraft. As requested by the Subcommittee on Defense of the House Appropriations Committee, this paper discusses some of the issues associated with the re-engining programs and illustrates the costs and effects of alternative approaches to re-engining. In accordance with CBO's mandate to provide objective analysis, no recommendations are made.

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BACKGROUND AND INTRODUCTION

The Air Force maintains a fleet of specialized tanker aircraft that can refuel bombers and other military aircraft while airborne. Aerial refueling extends the range of strategic bombers and would allow them to fly, for example, from the United States and attack targets inside the Soviet Union with nuclear weapons. It also extends the range and time on station of conventional fighters and bombers that would participate in non-nuclear conflicts in Europe and elsewhere.

The Air Force currently has some 615 KC-135 aircraft, which account for the bulk of its tanker fleet. 1/ The average age of these tankers in the active force is 23 years; those in the Air National Guard and Air Force Reserve average 26 years. A program to reskin the wings of the entire fleet, including special mission aircraft, and thus increase the service life of the air frames by at least 20 years will be completed in 1987 at a cost of about $528 million. In addition, two programs to replace the engines in these aircraft--one initiated by the Air Force, the other undertaken solely at the behest of the Congress--represent a multibillion-dollar effort to maintain the viability of these aircraft and enable them to meet an increased demand for aerial refueling.

Re-engining with the CFM-56. Under the Air Force-preferred re-engining program, initiated in 1977, the J57 engines on KC-135As are being replaced with new CFM-56 engines. 2/ This program also includes broad modernization of aircraft systems and subsystems. The first of the re-engined aircraft, designated KC-135R, was delivered to McConnell Air Force Base on July 2, 1984. The plan currently calls for re-engining a total of 392 tankers at a cost of $8.2 billion (in current dollars). Fifty-eight re-enginings are on contract through 1984.

Re-engining with the JT-3D. Begun in 1982, the Congressionally directed program salvages and refurbishes Pratt and Whitney JT-3D engines and related equipment from retired Boeing 707 aircraft whose engines will not meet the more stringent noise and emissions standards for commercial aircraft that go into effect on January 1, 1985. Thus far, this program has not been directed to aircraft in the active force but rather has focused on Air National Guard units, particularly those not colocated with the active

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1. This number refers to Primary Authorized Aircraft (PAA) and does not include about 5 percent of the total aircraft normally in the maintenance pipeline and not available for use.

2. The CFM-56 engines are produced jointly by General Electric and Snecma, a French firm.

force. The program originally called for deliveries of re-engined aircraft to continue through October 1984, with a total of 96 Guard and 20 special-mission aircraft, all designated KC-135E, to be re-engined at a cost of about $500 million (in current dollars). With the recently passed fiscal year 1984 defense supplemental bill, it is anticipated that the remaining 8 Guard and 24 Air Force Reserve aircraft will also be re-engined with the JT-3D (for a total of 148 KC-135Es) and that modifications will continue through fiscal year 1985.

The relative merits of these two re-engining programs vary depending on what measures (for example, capability, cost, timing, support requirements) are being examined. This paper first compares capability and cost characteristics of the aircraft produced under each program. It then reviews other issues to be considered in assessing the relative merits of the two programs, and summarizes the discussion by comparing the effects over time of alternative re-engining approaches.

CAPABILITY AND COST CHARACTERISTICS OF THE KC-135R AND KC-135E

Capability

As mentioned above, the CFM-56 re-engining program (KC-135R) includes broad replacements to or updates of a number of aircraft systems and subsystems (see Table 1, which shows the modifications to be undertaken in each program). Most of these modifications were required to accommodate the greater power and fuel carrying capacity of the CFM-56 engines. According to official estimates by the Department of Defense (DoD), the fuel delivery capacity of the re-engined KC-135R will increase by an average of 50 percent over that of the existing KC-135A; fuel efficiency is expected to increase by 25 percent. (These estimates are based on average fuel delivery capacities of the aircraft at specified distances; thus this measure is quite sensitive to the ranges and diversity of types of missions.) In addition, the KC-135R requires a shorter takeoff distance at maximum gross weight than the KC-135A. According to DoD, this will enable KC-135R tankers to land at 130 additional airfields in the United States and an additional 141 airfields in NATO countries. Other features unique to this re-engining program include strengthened main landing gear, auxiliary power units for quick start of all electrical systems, and some new instrument and control systems.

The JT-3D re-engining program is more limited in scope, mostly involving refurnishing the salvaged engines but also including some

TABLE 1. MODIFICATIONS OF THE KC-135R AND KC-135E

KC-135R (CFM-56)	KC-135E (JT-3D)
New engine (no thrust reversers)	Refurbished engine (thrust reverser)
Removes water injection system	Removes water injection system
New fire detection and extinguishing system	
Adds turbine engine monitor system	
New generators	
New airbleed system	
Adds dual APU quick start system	Cartridge start system
Adds new series Yaw damper	Adds 707 Yaw damper
Adds flight control augmentation system	
Adds larger horizontal stabilizer	Adds 707-100 stabilizer
Adds new rudder actuator	
Adds strengthened main landing gear	
Adds 5-rotor brakes	Adds 5-rotor brakes
Adds Mark III antiskid system	Adds Mark III antiskid system
Adds Rudder Pedal Control Nose Steering	
Adds new air data computer	
Adds new engine instruments	Adds used engine instruments

SOURCE: U.S. Air Force.

modifications to aircraft systems (see Table 1). 3/ According to DoD estimates, the JT-3D re-engining program is expected to increase fuel delivery capacity of the KC-135Es by an average of 20 percent over that of the KC-135A and to increase fuel efficiency by about 12 percent. Like the KC-135R, the E version will require a shorter takeoff distance and so will have access to more airfields. The addition of thrust reversers also gives the KC-135E some additional landing capability under adverse weather conditions that the KC-135R lacks. For instance, in icy conditions a KC-135E could land with more remaining fuel--which makes the aircraft heavier and harder to stop--than could a KC-135R, which has no thrust reversers. 4/

Both programs permit removal of the water-injection systems that are a source of logistics problems and noise for the current KC-135As. In fact, the noise and smoke created by the KC-135As landing at bases near metropolitan areas have long resulted in local complaints. In this respect, the JT-3D represents a significant improvement in noise and emissions over the current engines on the KC-135A. Unlike the CFM-56, however, it does not meet the more rigid noise and emission standards that will go into effect for commercial aircraft in 1985. Although the military is exempt from complying with these standards, the KC-135R will meet with all commercial regulations. The water-injection takeoff system also limits the access of the KC-135As to places where distilled water supplies are difficult to obtain, such as some areas in the Middle East. Without this system, both types of re-engined tankers will provide more geographical flexibility.

The performance characteristics of the KC-135A tanker and the two re-engined versions are summarized below:

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3. The refurbished engines would provide about 6,000 service hours of operation. At the current flying pace, the engines would last about 20 years.

4. The commercial version of the CFM-56 engine has thrust reversers, but owing to cost and weight considerations, coupled with the lack of a stated requirement for thrust reversers, the Air Force chose to have them removed in the military version of the engine. On an icy runway, with 10,000 pounds of remaining fuel, thrust reversers enable the KC-135E to land on a 5,565-foot runway while the KC-135R requires 6,450 feet. The runway length requirements for takeoff (at a mission-effective weight), however, are substantially greater than those for landing for both aircraft, and the KC-135R has some advantage here. Thus it would be difficult to quantify the operational advantage provided by thrust reversers; however, they do provide an added margin of safety.

	KC-135A	KC-135E	KC-135R
Maximum Gross Weight (lb)	292,000	297,000	322,500
Takeoff Distance (ft) at Maximum Gross Weight	11,200	9,600	8,100
Fuel Loads at Maximum Gross Weight (lb)	189,700	190,000	202,800
Fuel Delivery (lb) at 2,500 nm. Radius	63,000	75,600	94,500
Fuel Efficiency (% Improvement)	--	12	25
Compliance with Commercial Noise Standards as of Jan. 1, 1985	No	No	Yes
Smoke Pollution (% Reduction)	--	74	92

Cost

Without accounting for differences in capability, CFM-56 re-engining is much more costly than JT-3D re-engining. The procurement unit cost (in 1985 dollars) for the KC-135R is about $17.9 million, or around four times the $4.7 million unit cost for the KC-135E. Annual operating and support costs for the KC-135R and KC-135E are $2.0 million and $2.1 million, respectively. The difference arises mostly from fuel costs and thus is sensitive to changes in flying hours and fuel prices. This yields an undiscounted 20-year life cycle cost (excluding research and development) of $57.9 million for the KC-135R and $46.7 million for the KC-135E. 5/

Of course, the KC-135R and KC-135E do have differing capabilities. By applying the DoD estimates of relative fuel delivery capacity (in KC-135A equivalents) of 1.5:1 for the KC-135R and 1.2:1 for the KC-135E, the life-cycle costs per A-equivalent (including acquisition) become very similar: $38.6 million for the KC-135R, $38.9 million for the KC-135E.

When comparing costs per-KC-135A equivalent, the sensitivity of the equivalency ratios to many key assumptions should be kept in mind. As

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5. These estimates are derived from data supplied by the Air Force and DoD.

discussed above, tanker performance can vary greatly depending on the range and type of the mission. Large tankers, for example, may operate most efficiently on long missions. Also, the marginal contribution of a more capable re-engined tanker declines as the numbers of re-engined tankers increase. This occurs because the more demanding missions will have been assigned to the preceding re-engined tankers.

OTHER ISSUES

Availability of Aircraft for Re-engining

Since the JT-3D program involves salvaging and refurbishing existing commercial engines and other aircraft components, it is ultimately limited by the available supply of donor Boeing 707 aircraft. (There is no constraint on the supply of engines themselves.) As of a year or so ago, there were over 600 such aircraft available worldwide. The Air Force had stated that, of this supply, at least 200 suitable aircraft could be found. 6/ As noted above, of those suitable aircraft, 148 (including those from the fiscal year 1984 supplemental defense authorization) have thus far been committed to the re-engining program, leaving about 50 more aircraft available according to the Air Force.

There may, however, be more than 50 additional suitable candidates. According to an informal spokesman from the Federal Aviation Administration, the approximately 400 additional Boeing aircraft still available worldwide were all built to meet U.S. aviation standards, and all but a few have probably received continued care and maintenance according to international civil aviation standards. Air Force sources have said that since none of these internationally owned Boeing 707s have yet been examined by the Air Force, they can only speculate about the number of aircraft that may be available and suitable.

Beginning in 1985, however, commercial 707s will not be permitted to operate in U.S. airspace. Without further commitment for military purchases of these aircraft before that time, domestic aircraft may be scrapped or sold overseas. Thus for the near term, continuity in the JT-3D program may be the most important ingredient in ensuring a steady supply of aircraft for re-engining.

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6. Cited in General Accounting Office, Potential for Reducing Costs by Using JT-3D Engines in the KC-135 Re-engining Program (September 23, 1983), p. 6.

Aging

The desirability of investing in a re-engining program--especially the expensive CFM-56 program--may be influenced by the age of the KC-135 aircraft and the likely time required to complete the program. Owing to fiscal constraints, both the Congress and DoD have consistently cut back on the annual requests for aircraft to be re-engined with the CFM-56. As it stands now, the program will not be completed before 1991 at the earliest, with 1993 or 1994 the more probable completion date. Although the structure of the reskinned KC-135 will have at least another 20 years of service life, the re-engined aircraft delivered in 1991 will be about 30 years old.

By the early- to mid-1990s, these tankers will be supporting an almost completely modernized strategic bomber force and a significantly modernized tactical fighter force. These forces may also be facing an evolving and expanding air defense threat by the Soviet Union that may include over-the-horizon radars, long-range advanced warning and control systems (AWACS) aircraft, and look-down/shoot-down fighter aircraft. An important to question to consider, then, may be whether the missions for which the investments in the bomber force are being made would be at all compromised by the much older technology and perhaps increasing vulnerability of the supporting tankers. For instance, would an advanced ("stealth") technology bomber be easier to find because of the large radar cross-section of the accompanying tanker? If a new-generation tanker will be needed to support a smaller but more advanced bomber force in the future--a requirement the Air Force is said to be examining--it may be more important to consider cost-effective alternatives for current tanker re-engining.

Support Requirements

Some concern has been expressed by the Air Force about problems of logistics support for the JT-3D engines. There is more variability among the engines than if they had all been operated and maintained by the same source, which reportedly makes them more difficult to maintain and support than new engines. Others point out, however, that the JT-3D is basically the same engine that is currently in the active force on B-52H bombers and that 80 percent of the JT-3D engine parts are common with these engines and are federally stock listed.

According to informal Air Force sources, some logistics problems stemmed from a lack both of spare parts and of information about which spare parts and support would be required. The fiscal year 1985 Air Force

budget, however, contains funds for a substantial procurement of spare parts, and this problem should be alleviated.

Timing of Capability and Demand

Because of the dynamics of the demand for aerial refueling support, the time in which alternative re-engining programs can be completed may be an important consideration. The re-engining programs are primarily aimed at supporting increased demand for aerial refueling on the part of both strategic and general-purpose forces. According to an earlier CBO study, the increasing demand on the part of the strategic forces would be a near-term phenomenon, with demand peaking around 1988 and later decreasing. 7/ The increased demand into the mid- to late-1980s would result primarily from the introduction of the "shoot-and-penetrate" mission for the B-52 bombers in which bombers carry cruise missiles externally as well as other weapons internally. The extra weight--which displaces fuel--and the added air resistance ("drag") of the external weapons increase fuel and tanker requirements. Over the longer term, with the conversion to stand-off roles and the retirements of some B-52s, the requirements of the strategic bomber force for aerial refueling would decrease. This may be one argument in favor of a re-engining program that provides capability quickly.

Tanker demands in support of general-purpose forces could alter this argument. In Air Force and DoD analyses, support of general-purpose forces has supplanted strategic requirements as the driver behind the increasing demand for tankers. This shift in emphasis largely reflects an Administration policy goal to develop rapid force projection capabilities to several theaters of potential conflict such as NATO countries, Southwest Asia, and the Pacific in addition to supporting the strategic requirements. It is generally true, however, that there is more flexibility with respect to alternatives to aerial refueling for general-purpose missions than for strategic missions. Therefore, whether or not this demand would offset the decreasing requirements of the strategic forces is a question beyond the scope of this analysis.

Implications for the Guard and Reserve

As mentioned above, the Congress has focused the JT-3D re-engining program on the KC-135s in the Air National Guard and, most recently, in

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7. Congressional Budget Office, Aerial Tanker Force Modernization (March 1982).

the Air Force Reserve. By doing so, they have increased the capabilities of the Guard's operations worldwide.

The Guard and Reserve, however, do not maintain backup aircraft in their inventory. Thus, unless JT-3D re-engining continues, there will be no backup KC-135E aircraft. Air Force spokesmen have said that they would not mix aircraft with different engines within a unit; therefore, if the Guard were to lose one of its aircraft in an accident, it would either have to make do--which is difficult since the units are already small--or replace it with a C-135E from the active inventory. Currently, only special-mission aircraft in the active inventory have been re-engined with the JT-3D, and this would be an inefficient use of a specially configured aircraft. Moreover, there would be no flexibility to expand the Guard's mission without mixing aircraft types.

ALTERNATIVE APPROACHES FOR TANKER RE-ENGINING

As the preceding discussion suggests, both the JT-3D and CFM-56 re-engining programs have advantages and disadvantages. To help put their relative merits in perspective, CBO examined three approaches for increasing the Air Force's tanker capability.

- o Continue the current CFM-56 re-engining program at the maximum rate of six per month, for a total of 334 additional re-engined KC-135R aircraft (501 aircraft in KC-135A equivalents);
- o Continue the CFM-56 re-engining program at a reduced maximum rate of four per month, for a total of 334 additional re-engined KC-135R aircraft (501 aircraft in KC-135A equivalents);
- o Combine the JT-3D and CFM-56 re-engining programs at a maximum rate of six per month, for a total of 334 additional re-engined aircraft--166 KC-135Es with JT-3D engines, and 168 KC-135Rs with CFM-56 (or 451 aircraft in KC-135A equivalents).

The delivered capability (in KC-135A equivalents--1.5 for the CFM-56/KC-135R, and 1.2 for the JT-3D/KC-135E) and cost for each approach are summarized in Table 2. The top line shows deliveries from authorizations made through 1984. This line reflects, by 1986, the capability of 128 KC-135E aircraft for the Guard and Reserve (not including 20 special-mission aircraft) and 58 KC-135R aircraft, which would supplement the capability reflected in any of the alternative approaches.

The first approach in Table 2 illustrates the current Air Force plan to re-engine 334 KC-135Rs beyond 1984 as reflected in the December 1983 Selected Acquisition Report. Following this approach, the Air Force plans

TABLE 2. CUMULATIVE ADDITIONS TO TANKER CAPABILITY FROM RE-ENGINED AIRCRAFT (In KC-135A equivalents) a/

	End of Fiscal Year											Investment Cost (In billions of current dollars)	
	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1985-1989	Total
Deliveries from Previous Authorizations through 1984 b/	110	196	241	241	241	241	241	241	241	241	241		
Additions from Future Authorizations													
CFM-56 at Maximum Rate of 6 per Month c/		0	6	105	206	314	422	501	501	501	501	7.0	7.1
CFM-56 at Maximum Rate of 4 per Month d/		0	6	56	116	188	260	332	404	476	501	5.0	7.4
Combined CFM-56 and JT-3D at Maximum Rate of 6 per Month e/		0	46	135	233	330	414	451	451	451	451	4.2	4.3

a. Using DoD estimates of 1.5:1 capability for the KC-135R and 1.2:1 capability for the KC-135E.
b. Reflects deliveries of 58 KC-135Rs and 128 KC-135Es through 1986.
c. Reflects delivery schedule supplied by the Air Force.
d. Reflects delivery schedule supplied by the Air Force.
e. Assumes deliveries of 33 JT3Ds in 1986, 36 JT3Ds annually from 1987 through 1989, and 25 in 1990. CFM-56 deliveries are based on schedule supplied by the Air Force.

to build to a maximum re-engining rate of six aircraft per month. The second re-engining approach illustrates the effect of a probable outcome of the Air Force plan given past Congressional action based on fiscal constraints. It adjusts for Congressional action to date on the fiscal year 1985 budget and further assumes a likely maximum of four aircraft re-enginings per month. The third approach illustrates the effect of combining a slower rate of CFM-56 re-engining (three per month) with less expensive JT-3D re-engining (also three per month) to achieve the planned re-engining rate of six per month, for a total of 334 re-engined aircraft. This combined alternative would re-engine 166 aircraft with the JT-3D--more than the minimum of 50 remaining aircraft that the Air Force described, but substantially less than the remaining worldwide supply of about 400 aircraft.

Pros and Cons of the Different Approaches

The combined JT-3D/CFM-56 approach offers several advantages over the other two alternatives. It offers more capability through 1989 than either the CFM-56 six-per-month program or the four-per-month program that may be the more probable outcome of the budget debate; the combined alternative also offers more capability through 1992 than the four-per-month program. It offers this higher near-term capability, which may be consistent with higher near-term tanker demand for strategic missions, while reducing five-year investment costs by a total of $2.8 billion relative to the Air Force's six-per-month program. 8/ Some of the near-term savings from this alternative could be invested in development of a new tanker if the Air Force believes that additional technical improvements will be needed in the 1990s. Having the CFM-56 and JT-3D programs ongoing also offers some competitive pressure to keep costs down, particularly engine costs. Although Boeing currently does the modification and integration for both re-engining programs, the CFM-56 engines are purchased directly from General Electric, while the JT-3D engines are from the donor Boeing 707 aircraft.

The combined approach also has several potential drawbacks. First, putting JT-3D re-engined tankers into the active force rather than just into the Guard and Reserves would represent a change of direction. But this may not be a problem in that the basic JT-3D engine now powers the B-52H and some special-mission aircraft already in the active force. Thus, basing the KC-135Es with these aircraft may actually exploit economies of scale for

8. According to the Air Force, the investment costs they supplied for CFM-56 re-engining contain conservative risk factors, so actual savings may be less.

spare parts and technical support. 9/ Having KC-135Es in the active force would also increase the availability of backup aircraft for the Guard and Reserve and for an expanded Guard mission. Second, in the longer run, the combined alternative would provide about 50 fewer KC-135A equivalents than either approach involving the pure CFM-56 re-engining; however, a CFM-56 production line would be open so re-engining could continue if more capability was later deemed necessary. Finally, the age and variability among the JT-3D engines may make them more difficult and costly to maintain.

The pure CFM-56 re-engining approaches also offer advantages. The CFM-56 is a brand new engine, and although it is not yet proven reliable like the JT-3D, it is inherently more capable. There may be some missions, for instance, that would require only one KC-135R with the CFM-56, but two KC-135Es with the JT-3D. Moreover, in the long run the CFM-56 may cost no more. Air Force estimates of life-cycle costs suggest that, over 20 years, the cost would be about the same to use either JT-3D or CFM-56 re-engining to provide equal amounts of capability. Finally, the CFM-56 is quiet and meets the noise and emissions standards that apply to nonmilitary aircraft.

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9. The current Air Force basing plan has B-52H aircraft stationed at the following bases: K.I. Sawyer, Dyess, Carswell, Ellsworth, and Minot.